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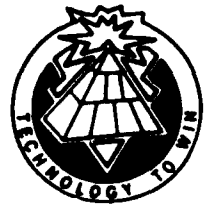
VERTICAL MOLECULAR ABSORPTION COEFFICIENT PROFILES AND ASSOCIATED METEOROLOGICAL DATA AT THE HIGH ENERGY LASER SYSTEMS TEST FACILITY FOR 20 AUGUST 1991

September 1992

Frank T. Kantrowitz



US ARMY
LABORATORY COMMAND
ATMOSPHERIC SCIENCES LABORATORY
White Sands Missile Range, NM 88002-5501

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In support of White Sands Missile Range high energy laser operations for 20 August 1991, the U.S. Army Atmospheric Sciences Laboratory was tasked to calculate simulated molecular absorption coefficient vertical profiles by using the U.S. Air Force Phillips Laboratory Geophysics Directorate (formerly the U.S. Air Force Geophysics Laboratory) transmittance and radiance program FASCOD2.

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CONTENTS

LIST OF ILLUSTRATIONS

Tables

Figures

1. INTRODUCTION

Performance of the mid-infrared chemical laser (MIRACL) at the High Energy Laser Systems Test Facility degrades somewhat because of thermal blooming that results from molecular and aerosol absorption of beam energy. At the mid-infrared directed frequency (DF) wavelengths studied in this report, molecular continuum and line absorption are usually the most important absorption mechanisms. The simulated molecular absorption coefficient vertical profiles presented here are a follow up to earlier reports (Kantrowitz, 1991; O'Brien et al., 1989). Profiles are calculated by using the U.S. Air Force Phillips Laboratory Geophysics Directorate (formerly the U.S. Air Force Geophysics Laboratory) transmittance and radiance program FASCOD2 and the high resolution molecular database HITRAN (Kantrowitz, 1990; Clough et al., 1986; Smith et al., 1981). Radiosonde data for the morning of 20 Aug 91 were input for a user-supplied atmospheric profile in the lower atmosphere and the Phillips Laboratory mid-latitude summer model was used in the upper atmosphere. Both average and laser power-weighted profile plots were generated.

Output from FASCOD2 is given as the optical depth, which is a unitless quantity that describes the degree of attenuation. The optical depth for a homogeneous path or slant segment is given by

$$D(\nu) = k(\nu)\, x$$

where $k(\nu)$ is the absorption coefficient, ν is the frequency, and x is the path length. It is convenient to be able to define a single power-weighted absorption coefficient to represent the fraction of the total laser power in a line. The percentage of total power in each spectral line is displayed in table 1 and figure 1.* A more detailed description of the calculations used in the data analysis is given in the 27 Feb 91 report.

2. METEOROLOGICAL DATA

A radiosonde was launched from the Small Missile Range at White Sands Missile Range (WSMR), New Mexico, on the morning of 20 Aug 91. The instrument package reached an altitude of 17.2 km. The temperature, pressure, and water-related data (relative humidity and dew point) were measured to an altitude of approximately 10.3 km. Surface data and radiosonde data from 1.25 to 10.3 km were input into FASCOD2. For altitudes greater than this, Phillips Laboratory mid-latitude summer data were used (Anderson et al., 1986). Tables 2 and 3 and figures 2, 3, and 4 show the sonde and model data. In these figures, the circles denote sonde data and the triangles denote model data.

3. VERTICAL PROFILES OF MOLECULAR ABSORPTION

The molecular species considered are oxygen, water vapor, carbon dioxide, methane, nitrous oxide, carbon monoxide, and ozone (Park et al., 1987). The High Energy Laser (HEL) Propagation Handbook (1984) contains the vertical profile information for the lowest 10 km for each of these atmospheric constituents. The Phillips Laboratory mid-latitude summer model is in good

*Tables and figures are presented at the end of the text.

agreement with the HEL handbook except for temperature, pressure and water vapor content, all of which are quite variable. For these inputs to FASCOD2, sonde data were applied. The major exception is the methane profile since WSMR is located in a desert climate that produces lower than average methane concentrations. The user-supplied atmospheric profile adopted for the lower regions of the atmosphere does mimic the HEL handbook profile, but uses the Phillips Laboratory profile for the upper reaches of the atmosphere.

Tables 4 through 8 and figures 5 through 9 show molecular absorption coefficient profiles. Table 9 and figure 10 show averaged and laser power-weighted absorption coefficient profiles.

5. CONCLUDING REMARKS

The simulated molecular absorption coefficient vertical profiles presented here were calculated by using the Phillips Laboratory Geophysics Directorate transmittance and radiance program FASCOD2. Radiosonde data for the morning of 20 Aug 91 were input for a user-supplied atmospheric profile in the lower atmosphere, and the Phillips Laboratory mid-latitude summer model was used in the upper atmosphere. Both average and laser power-weighted profile plots were generated.

MIRACL performance does appear to degrade somewhat because of molecular absorption of beam energy. At the mid-infrared DF wavelengths studied in this report, molecular continuum and line absorption were found to be important absorption mechanisms. Water vapor appears to be the strongest attenuator in this spectral region.

TABLE 1. DF LINE POSITIONS AND PERCENTAGE OF TOTAL POWER PER LINE

Spectral Line	Wavelength (microns)	Percent Total Power in Spectral Line
MIRACL Power at:		41%
P1(7)	3.645	10.8
P1(8)	3.679	19.2
P1(9)	3.715	9.5
P2(6)	3.731	3.5
P1(10)	3.752	1.5
P2(7)	3.764	11.8
P2(8)	3.801	12.9
P2(9)	3.837	3.2
P3(6)	3.854	12.2
P3(7)	3.890	8.8
P3(8)	3.927	4.5
P3(9)	3.966	0.3
P4(6)	3.984	1.0
P4(7)	4.022	0.7

TABLE 2. RADIOSONDE DATA USED IN FASCOD2 CALCULATIONS

Altitude (km)	Pressure (mbar)	Temperature (K)	Relative Humidity (%)
1.250	880.000	291.15	85.86
1.500	857.000	293.85	63.35
1.750	833.000	293.15	62.78
2.000	810.000	292.05	64.21
2.250	786.000	290.65	64.76
2.750	741.000	287.25	64.31
3.250	699.000	283.45	71.31
3.750	658.000	280.50	73.24
4.250	619.000	277.75	60.64
4.750	582.000	274.64	50.29
5.250	547.000	270.99	57.59
5.750	513.000	267.63	78.51
6.250	482.000	264.94	67.27
6.750	452.000	262.15	56.28
7.250	423.000	258.75	60.85
7.750	396.000	255.05	79.33
8.250	370.000	252.35	74.10
8.750	346.000	248.25	69.93
9.250	323.000	244.75	71.14
9.750	301.000	241.25	70.33
10.300	280.000	237.55	68.02

TABLE 3. MID-LATITUDE SUMMER MODEL DATA USED IN FASCOD2 CALCULATIONS

Altitude (km)	Pressure (mbar)	Temperature (K)	Relative Humidity (%)
10.800	250.253	230.10	22.14
11.300	232.377	226.85	16.56
13.800	157.934	215.51	3.06
16.300	105.927	215.65	1.34
18.800	71.693	217.67	0.69
21.300	48.682	220.76	0.35
23.800	33.212	223.68	0.20
26.300	22.799	226.71	0.10
28.800	15.727	231.06	0.05
31.300	10.994	236.40	0.02
35.000	6.520	245.20	0.01
37.500	4.640	251.30	0.00
40.000	3.330	257.50	0.00
42.500	2.410	263.70	0.00
45.000	1.760	269.9	0.00
47.500	1.290	275.20	0.00
50.000	0.951	275.70	0.00
52.500	0.701	273.53	0.00
55.000	0.515	269.30	0.00
57.500	0.376	263.86	0.00
60.000	0.272	257.10	0.00
65.000	0.139	240.10	0.00
70.000	0.067	218.10	0.00
75.000	0.030	196.10	0.01
80.000	0.012	174.10	0.07
85.000	0.004	165.10	0.12
90.000	0.002	165.00	0.03
95.000	0.001	176.30	0.00
100.000	0.000	190.50	0.00

TABLE 4. MOLECULAR COEFFICIENTS FOR 3.645, 3.679, AND 3.715 μm

MINALT (km)	MAXALT (km)	Molecular Absorption Coefficients 3.645 μm (km^{-1})	3.679 μm (km^{-1})	3.715 μm (km^{-1})
0.000	0.250	0.3487000E-01	0.1037000E+00	0.3361000E-01
0.250	0.500	0.3099000E-01	0.9358000E-01	0.2949000E-01
0.500	0.750	0.2922000E-01	0.8876000E-01	0.2787000E-01
0.750	1.000	0.2726000E-01	0.8311000E-01	0.2607000E-01
1.000	1.500	0.2333000E-01	0.7513000E-01	0.2249000E-01
1.500	2.000	0.1847000E-01	0.5289000E-01	0.1721000E-01
2.000	2.500	0.1563000E-01	0.4337000E-01	0.1470000E-01
2.500	3.000	0.1183000E-01	0.3232000E-01	0.1134000E-01
3.000	3.500	0.7539000E-02	0.1817000E-01	0.7215000E-02
3.500	4.000	0.5762000E-02	0.1382000E-01	0.5558000E-02
4.000	4.500	0.5503000E-02	0.1319000E-01	0.5309000E-02
4.500	5.000	0.4737000E-02	0.1132000E-01	0.4639000E-02
5.000	5.500	0.3055000E-02	0.6532000E-02	0.3047000E-02
5.500	6.000	0.2314000E-02	0.4902000E-02	0.2401000E-02
6.000	6.500	0.2056000E-02	0.4320000E-02	0.2169000E-02
6.500	7.000	0.1758000E-02	0.3658000E-02	0.1904000E-02
7.000	7.500	0.1199000E-02	0.2272000E-02	0.1313000E-02
7.500	8.000	0.9092000E-03	0.1680000E-02	0.1073000E-02
8.000	8.500	0.7216000E-03	0.1302000E-02	0.9092000E-03
8.500	9.000	0.5404000E-03	0.9080000E-03	0.6636000E-03
9.000	9.500	0.3708000E-03	0.5860000E-03	0.5192000E-03
9.500	10.000	0.2666000E-03	0.3880000E-03	0.4256000E-03
10.000	12.500	0.2371000E-03	0.2800000E-03	0.2380000E-03
12.500	15.000	0.2180000E-03	0.1740000E-03	0.1009000E-03
15.000	17.500	0.2101000E-03	0.1068000E-03	0.3968000E-04
17.500	20.000	0.1701000E-03	0.6480000E-04	0.1784000E-04
20.000	22.500	0.1623000E-03	0.2960000E-04	0.5999000E-05
22.500	25.000	0.1189000E-03	0.1640000E-04	0.2763000E-05
25.000	27.500	0.1031000E-03	0.7600000E-05	0.1040000E-05
27.500	30.000	0.7508000E-04	0.4399000E-05	0.5186000E-06
30.000	33.750	0.5093000E-04	0.2400000E-05	0.2404000E-06
33.750	36.250	0.3304000E-04	0.1198000E-05	0.1192000E-06
36.250	38.750	0.2336000E-04	0.1204000E-05	0.8047000E-07
38.750	41.250	0.1636000E-04	0.3994000E-06	0.0000000E+00
41.250	43.750	0.1144000E-04	0.3994000E-06	0.0000000E+00
43.750	46.250	0.8041000E-05	0.3994000E-06	0.0000000E+00
46.250	48.750	0.5761000E-05	0.0000000E+00	0.0000000E+00
48.750	51.250	0.4241000E-05	0.0000000E+00	0.0000000E+00
51.250	53.750	0.3159000E-05	0.0000000E+00	0.0000000E+00
53.750	56.250	0.2238000E-05	0.0000000E+00	0.0000000E+00
56.250	58.750	0.1723000E-05	0.0000000E+00	0.0000000E+00
58.750	63.750	0.1140000E-05	0.0000000E+00	0.0000000E+00
63.750	68.750	0.6199000E-06	0.0000000E+00	0.0000000E+00
68.750	73.750	0.2995000E-06	0.0000000E+00	0.0000000E+00
73.750	78.750	0.1401000E-06	0.0000000E+00	0.0000000E+00
78.750	83.750	0.0000000E+00	0.0000000E+00	0.0000000E+00
83.750	88.750	0.0000000E+00	0.0000000E+00	0.0000000E+00
88.750	93.750	0.0000000E+00	0.0000000E+00	0.0000000E+00
93.750	98.750	0.0000000E+00	0.0000000E+00	0.0000000E+00

TABLE 5. MOLECULAR COEFFICIENTS FOR 3.731, 3.752, AND 3.764 μm

MINALT (km)	MAXALT (km)	Molecular Absorption Coefficients 3.731 μm (km^{-1})	3.752 μm (km^{-1})	3.764 μm (km^{-1})
0.000	0.250	0.6464000E-01	0.3682000E-01	0.4643000E-01
0.250	0.500	0.5796000E-01	0.3280000E-01	0.4149000E-01
0.500	0.750	0.5511000E-01	0.3103000E-01	0.3929000E-01
0.750	1.000	0.5183000E-01	0.2905000E-01	0.3679000E-01
1.000	1.500	0.4498000E-01	0.2526000E-01	0.3168000E-01
1.500	2.000	0.3300000E-01	0.1944000E-01	0.2346000E-01
2.000	2.500	0.2847000E-01	0.1669000E-01	0.2002000E-01
2.500	3.000	0.2205000E-01	0.1304000E-01	0.1532000E-01
3.000	3.500	0.1300000E-01	0.8376000E-02	0.9238000E-02
3.500	4.000	0.1017000E-01	0.6720000E-02	0.7165000E-02
4.000	4.500	0.9822000E-02	0.6361000E-02	0.6842000E-02
4.500	5.000	0.8592000E-02	0.5578000E-02	0.5898000E-02
5.000	5.500	0.5262000E-02	0.3810000E-02	0.3640000E-02
5.500	6.000	0.4082000E-02	0.3104000E-02	0.2804000E-02
6.000	6.500	0.3670000E-02	0.2790000E-02	0.2488000E-02
6.500	7.000	0.3182000E-02	0.2456000E-02	0.2136000E-02
7.000	7.500	0.2022000E-02	0.1756000E-02	0.1388000E-02
7.500	8.000	0.1556000E-02	0.1463000E-02	0.1066000E-02
8.000	8.500	0.1242000E-02	0.1250000E-02	0.8480000E-03
8.500	9.000	0.8300000E-03	0.9300000E-03	0.5860000E-03
9.000	9.500	0.5500000E-03	0.7488000E-03	0.4000000E-03
9.500	10.000	0.3700000E-03	0.6118000E-03	0.2760000E-03
10.000	12.500	0.1812000E-03	0.3348000E-03	0.1492000E-03
12.500	15.000	0.7200000E-04	0.1384000E-03	0.6280000E-04
15.000	17.500	0.2680000E-04	0.5356000E-04	0.2520000E-04
17.500	20.000	0.1080000E-04	0.2232000E-04	0.1120000E-04
20.000	22.500	0.3600000E-05	0.7439000E-05	0.4399000E-05
22.500	25.000	0.1597000E-05	0.3162000E-05	0.2000000E-05
25.000	27.500	0.8047000E-06	0.1198000E-05	0.8017000E-06
27.500	30.000	0.0000000E+00	0.5603000E-06	0.3994000E-06
30.000	33.750	0.2662000E-06	0.2146000E-06	0.2662000E-06
33.750	36.250	0.0000000E+00	0.7749000E-07	0.0000000E+00
36.250	38.750	0.0000000E+00	0.4172000E-07	0.0000000E+00
38.750	41.250	0.0000000E+00	0.0000000E+00	0.0000000E+00
41.250	43.750	0.0000000E+00	0.3874000E-07	0.0000000E+00
43.750	46.250	0.0000000E+00	0.0000000E+00	0.0000000E+00
46.250	48.750	0.0000000E+00	0.0000000E+00	0.0000000E+00
48.750	51.250	0.0000000E+00	0.0000000E+00	0.0000000E+00
51.250	53.750	0.0000000E+00	0.0000000E+00	0.0000000E+00
53.750	56.250	0.0000000E+00	0.0000000E+00	0.0000000E+00
56.250	58.750	0.0000000E+00	0.0000000E+00	0.0000000E+00
58.750	63.750	0.0000000E+00	0.0000000E+00	0.0000000E+00
63.750	68.750	0.0000000E+00	0.0000000E+00	0.0000000E+00
68.750	73.750	0.0000000E+00	0.0000000E+00	0.0000000E+00
63.750	78.750	0.0000000E+00	0.0000000E+00	0.0000000E+00
78.750	83.750	0.0000000E+00	0.0000000E+00	0.0000000E+00
83.750	88.750	0.0000000E+00	0.0000000E+00	0.0000000E+00
88.750	93.750	0.0000000E+00	0.0000000E+00	0.0000000E+00
93.750	98.750	0.0000000E+00	0.0000000E+00	0.0000000E+00

TABLE 6. MOLECULAR COEFFICIENTS FOR 3.801, 3.837, AND 3.854 μm

MINALT (km)	MAXALT (km)	Molecular Absorption Coefficients 3.801 μm (km^{-1})	3.837 μm (km^{-1})	3.854 μm (km^{-1})
0.000	0.250	0.2549000E-01	0.2655000E+00	0.3020000E-01
0.250	0.500	0.2257000E-01	0.2408000E+00	0.2715000E-01
0.500	0.750	0.2115000E-01	0.2291000E+00	0.2561000E-01
0.750	1.000	0.1959000E-01	0.2151000E+00	0.2393000E-01
1.000	1.500	0.1657000E-01	0.1850000E+00	0.2088000E-01
1.500	2.000	0.1334000E-01	0.1478000E+00	0.1722000E-01
2.000	2.500	0.1115000E-01	0.1259000E+00	0.1482000E-01
2.500	3.000	0.8411000E-02	0.9604000E-01	0.1187000E-01
3.000	3.500	0.5701000E-02	0.5944000E-01	0.9066000E-02
3.500	4.000	0.4421000E-02	0.4527000E-01	0.7548000E-02
4.000	4.500	0.4128000E-02	0.4348000E-01	0.6979000E-02
4.500	5.000	0.3544000E-02	0.3749000E-01	0.6159000E-02
5.000	5.500	0.2539000E-02	0.2293000E-01	0.5187000E-02
5.500	6.000	0.2016000E-02	0.1705000E-01	0.4431000E-02
6.000	6.500	0.1793000E-02	0.1507000E-01	0.3971000E-02
6.500	7.000	0.1557000E-02	0.1272000E-01	0.3493000E-02
7.000	7.500	0.1207000E-02	0.7796000E-02	0.3175000E-02
7.500	8.000	0.9948000E-03	0.5524000E-02	0.2753000E-02
8.000	8.500	0.8502000E-03	0.4086000E-02	0.2407000E-02
8.500	9.000	0.6926000E-03	0.2548000E-02	0.2290000E-02
9.000	9.500	0.5636000E-03	0.1292000E-02	0.1921000E-02
9.500	10.000	0.4714000E-03	0.5620000E-03	0.1591000E-02
10.000	12.500	0.2982000E-03	0.2704000E-03	0.1302000E-02
12.500	15.000	0.1421000E-03	0.1168000E-03	0.8167000E-03
15.000	17.500	0.6168000E-04	0.5162000E-04	0.4519000E-03
17.500	20.000	0.2976000E-04	0.2320000E-04	0.2107000E-03
20.000	22.500	0.1212000E-04	0.9990000E-05	0.8264000E-04
22.500	25.000	0.6518000E-05	0.5198000E-05	0.4388000E-04
25.000	27.500	0.2360000E-05	0.1597000E-05	0.2024000E-04
27.500	30.000	0.1201000E-05	0.1216000E-05	0.1124000E-04
30.000	33.750	0.5066000E-06	0.2543000E-06	0.5148000E-05
33.750	36.250	0.1997000E-06	0.4053000E-06	0.2319000E-05
36.250	38.750	0.8047000E-07	0.0000000E+00	0.1240000E-05
38.750	41.250	0.3874000E-07	0.0000000E+00	0.6407000E-06
41.250	43.750	0.4172000E-07	0.0000000E+00	0.3874000E-07
43.750	46.250	0.0000000E+00	0.0000000E+00	0.4172000E-07
46.250	48.750	0.0000000E+00	0.0000000E+00	0.0000000E+00
48.750	51.250	0.0000000E+00	0.0000000E+00	0.0000000E+00
51.250	53.750	0.0000000E+00	0.0000000E+00	0.0000000E+00
53.750	56.250	0.0000000E+00	0.0000000E+00	0.0000000E+00
56.250	58.750	0.0000000E+00	0.0000000E+00	0.0000000E+00
58.750	63.750	0.0000000E+00	0.0000000E+00	0.0000000E+00
63.750	68.750	0.0000000E+00	0.0000000E+00	0.0000000E+00
68.750	73.750	0.0000000E+00	0.0000000E+00	0.0000000E+00
73.750	78.750	0.0000000E+00	0.0000000E+00	0.0000000E+00
78.750	83.750	0.0000000E+00	0.0000000E+00	0.0000000E+00
83.750	88.750	0.0000000E+00	0.0000000E+00	0.0000000E+00
88.750	93.750	0.0000000E+00	0.0000000E+00	0.0000000E+00
93.750	98.750	0.0000000E+00	0.0000000E+00	0.0000000E+00

TABLE 7. MOLECULAR COEFFICIENTS FOR 3.890, 3.927, AND 3.966 μm

MINALT (km)	MAXALT (km)	Molecular Absorption Coefficients 3.890 μm (km^{-1})	3.927 μm (km^{-1})	3.966 μm (km^{-1})
0.000	0.250	0.4984000E-01	0.3903000E-01	0.3078000E-01
0.250	0.500	0.4589000E-01	0.3566000E-01	0.2766000E-01
0.500	0.750	0.4380000E-01	0.3392000E-01	0.2604000E-01
0.750	1.000	0.4159000E-01	0.3203000E-01	0.2436000E-01
1.000	1.500	0.3766000E-01	0.2881000E-01	0.2139000E-01
1.500	2.000	0.3145000E-01	0.2405000E-01	0.1810000E-01
2.000	2.500	0.2842000E-01	0.2149000E-01	0.1571000E-01
2.500	3.000	0.2475000E-01	0.1840000E-01	0.1289000E-01
3.000	3.500	0.1926000E-01	0.1433000E-01	0.1018000E-01
3.500	4.000	0.1738000E-01	0.1270000E-01	0.8648000E-02
4.000	4.500	0.1655000E-01	0.1194000E-01	0.7887000E-02
4.500	5.000	0.1540000E-01	0.1093000E-01	0.6962000E-02
5.000	5.500	0.1222000E-01	0.8724000E-02	0.5764000E-02
5.500	6.000	0.1124000E-01	0.7862000E-02	0.4961000E-02
6.000	6.500	0.1062000E-01	0.7294000E-02	0.4438000E-02
6.500	7.000	0.9964000E-02	0.6720000E-02	0.3930000E-02
7.000	7.500	0.7880000E-02	0.5402000E-02	0.3362000E-02
7.500	8.000	0.7348000E-02	0.4942000E-02	0.2942000E-02
8.000	8.500	0.6864000E-02	0.4524000E-02	0.2588000E-02
8.500	9.000	0.5398000E-02	0.3670000E-02	0.2266000E-02
9.000	9.500	0.4976000E-02	0.3300000E-02	0.1946000E-02
9.500	10.000	0.4578000E-02	0.2964000E-02	0.1657000E-02
10.000	12.500	0.2622000E-02	0.1721000E-02	0.1132000E-02
12.500	15.000	0.1124000E-02	0.7584000E-03	0.5493000E-03
15.000	17.500	0.4016000E-03	0.2896000E-03	0.2458000E-03
17.500	20.000	0.1436000E-03	0.1156000E-03	0.1102000E-03
20.000	22.500	0.4200000E-04	0.3920000E-04	0.4800000E-04
22.500	25.000	0.1960000E-04	0.1680000E-04	0.2160000E-04
25.000	27.500	0.5603000E-05	0.6801000E-05	0.1000000E-04
27.500	30.000	0.2396000E-05	0.3201000E-05	0.4399000E-05
30.000	33.750	0.1069000E-05	0.1069000E-05	0.1866000E-05
33.750	36.250	0.0000000E+00	0.3994000E-06	0.8017000E-06
36.250	38.750	0.3994000E-06	0.3994000E-06	0.0000000E+00
38.750	41.250	0.0000000E+00	0.0000000E+00	0.3994000E-06
41.250	43.750	0.0000000E+00	0.0000000E+00	0.0000000E+00
43.750	46.250	0.0000000E+00	0.0000000E+00	0.0000000E+00
46.250	48.750	0.0000000E+00	0.0000000E+00	0.0000000E+00
48.750	51.250	0.0000000E+00	0.0000000E+00	0.0000000E+00
51.250	53.750	0.0000000E+00	0.0000000E+00	0.0000000E+00
53.750	56.250	0.0000000E+00	0.0000000E+00	0.0000000E+00
56.250	58.750	0.0000000E+00	0.0000000E+00	0.0000000E+00
58.750	63.750	0.0000000E+00	0.0000000E+00	0.0000000E+00
63.750	68.750	0.0000000E+00	0.0000000E+00	0.0000000E+00
68.750	73.750	0.0000000E+00	0.0000000E+00	0.0000000E+00
73.750	78.750	0.0000000E+00	0.0000000E+00	0.0000000E+00
78.750	83.750	0.0000000E+00	0.0000000E+00	0.0000000E+00
83.750	88.750	0.0000000E+00	0.0000000E+00	0.0000000E+00
88.750	93.750	0.0000000E+00	0.0000000E+00	0.0000000E+00
93.750	98.750	0.0000000E+00	0.0000000E+00	0.0000000E+00

TABLE 8. MOLECULAR COEFFICIENTS FOR 3.984 AND 4.022 μm

MINALT (km)	MAXALT (km)	Molecular Absorption Coefficients 3.984 μm (km^{-1})	4.022 μm (km^{-1})
0.000	0.250	0.3341000E-01	0.5097000E-01
0.250	0.500	0.3008000E-01	0.4668000E-01
0.500	0.750	0.2832000E-01	0.4416000E-01
0.750	1.000	0.2651000E-01	0.4154000E-01
1.000	1.500	0.2340000E-01	0.3725000E-01
1.500	2.000	0.2004000E-01	0.3243000E-01
2.000	2.500	0.1746000E-01	0.2871000E-01
2.500	3.000	0.1444000E-01	0.2454000E-01
3.000	3.500	0.1160000E-01	0.2054000E-01
3.500	4.000	0.9914000E-02	0.1805000E-01
4.000	4.500	0.9060000E-02	0.1654000E-01
4.500	5.000	0.8011000E-02	0.1485000E-01
5.000	5.500	0.6747000E-02	0.1281000E-01
5.500	6.000	0.5818000E-02	0.1138000E-01
6.000	6.500	0.5178000E-02	0.1030000E-01
6.500	7.000	0.4587000E-02	0.9274000E-02
7.000	7.500	0.4046000E-02	0.8082000E-02
7.500	8.000	0.3539000E-02	0.7240000E-02
8.000	8.500	0.3078000E-02	0.6486000E-02
8.500	9.000	0.2782000E-02	0.5622000E-02
9.000	9.500	0.2402000E-02	0.4932000E-02
9.500	10.000	0.2036000E-02	0.4276000E-02
10.000	12.500	0.1416000E-02	0.2795000E-02
12.500	15.000	0.6920000E-03	0.1319000E-02
15.000	17.500	0.3136000E-03	0.5696000E-03
17.500	20.000	0.1416000E-03	0.2464000E-03
20.000	22.500	0.6280000E-04	0.1044000E-03
22.500	25.000	0.2920000E-04	0.4760000E-04
25.000	27.500	0.1280000E-04	0.2080000E-04
27.500	30.000	0.6399000E-05	0.1000000E-04
30.000	33.750	0.2400000E-05	0.3731000E-05
33.750	36.250	0.8017000E-06	0.1597000E-05
36.250	38.750	0.3994000E-06	0.4053000E-06
38.750	41.250	0.3994000E-06	0.3994000E-06
41.250	43.750	0.0000000E+00	0.0000000E+00
43.750	46.250	0.0000000E+00	0.3994000E-06
46.250	48.750	0.0000000E+00	0.0000000E+00
48.750	51.250	0.0000000E+00	0.0000000E+00
51.250	53.750	0.0000000E+00	0.0000000E+00
53.750	56.250	0.0000000E+00	0.0000000E+00
56.250	58.750	0.0000000E+00	0.0000000E+00
58.750	63.750	0.0000000E+00	0.0000000E+00
63.750	68.750	0.0000000E+00	0.0000000E+00
68.750	73.750	0.0000000E+00	0.0000000E+00
73.750	78.750	0.0000000E+00	0.0000000E+00
78.750	83.750	0.0000000E+00	0.0000000E+00
83.750	88.750	0.0000000E+00	0.0000000E+00
88.750	93.750	0.0000000E+00	0.0000000E+00
93.750	98.750	0.0000000E+00	0.0000000E+00

TABLE 9. AVERAGE AND MIRACL WEIGHTED ABSORPTION COEFFICIENTS FOR 41% POWER

MINALT (km)	MAXALT (km)	Average (km^{-1})	MIRACL (km^{-1})
0.000	0.250	0.6037786E-01	0.5756655E-01
0.250	0.500	0.5448572E-01	0.5181757E-01
0.500	0.750	0.5167001E-01	0.4910882E-01
0.750	1.000	0.4848286E-01	0.4603067E-01
1.000	1.500	0.4241643E-01	0.4054188E-01
1.500	2.000	0.3349286E-01	0.3088529E-01
2.000	2.500	0.2875286E-01	0.2618944E-01
2.500	3.000	0.2266007E-01	0.2030326E-01
3.000	3.500	0.1526107E-01	0.1303305E-01
3.500	4.000	0.1236614E-01	0.1039788E-01
4.000	4.500	0.1168507E-01	0.9876581E-02
4.500	5.000	0.1029357E-01	0.8666070E-02
5.000	5.500	0.7304786E-02	0.5880610E-02
5.500	6.000	0.6026072E-02	0.4781570E-02
6.000	6.500	0.5439786E-02	0.4318981E-02
6.500	7.000	0.4809928E-02	0.3809410E-02
7.000	7.500	0.3635714E-02	0.2787620E-02
7.500	8.000	0.3073571E-02	0.2329787E-02
8.000	8.500	0.2654000E-02	0.2002165E-02
8.500	9.000	0.2123329E-02	0.1572307E-02
9.000	9.500	0.1750529E-02	0.1278767E-02
9.500	10.000	0.1462386E-02	0.1062968E-02
10.000	12.500	0.9269215E-03	0.6821430E-03
12.500	15.000	0.4488858E-03	0.3510610E-03
15.000	17.500	0.2033957E-03	0.1726536E-03
17.500	20.000	0.9415143E-04	0.8613460E-04
20.000	22.500	0.4389193E-04	0.4346610E-04
22.500	25.000	0.2394414E-04	0.2612174E-04
25.000	27.500	0.1391039E-04	0.1675576E-04
27.500	30.000	0.8643522E-05	0.1112530E-04
30.000	33.750	0.5025808E-05	0.6927972E-05
33.750	36.250	0.2925606E-05	0.4172684E-05
36.250	38.750	0.1972154E-05	0.2984091E-05
38.750	41.250	0.1331217E-05	0.1934835E-05
41.250	43.750	0.8541857E-06	0.1322370E-05
43.750	46.250	0.6343943E-06	0.9529650E-06
46.250	48.750	0.4115000E-06	0.6222000E-06
48.750	51.250	0.3029286E-06	0.4580000E-06
51.250	53.750	0.2256429E-06	0.3412000E-06
53.750	56.250	0.1598571E-06	0.2417000E-06
56.250	58.750	0.1230714E-06	0.1860000E-06
58.750	63.750	0.8142857E-07	0.1231000E-06
63.750	68.750	0.4427857E-07	0.6695000E-07
68.750	73.750	0.2139286E-07	0.3235000E-07
73.750	78.750	0.1000714E-07	0.1513000E-07
78.750	83.750	0.0000000E+00	0.0000000E+00
83.750	88.750	0.0000000E+00	0.0000000E+00
88.750	93.750	0.0000000E+00	0.0000000E+00
93.750	98.750	0.0000000E+00	0.0000000E+00

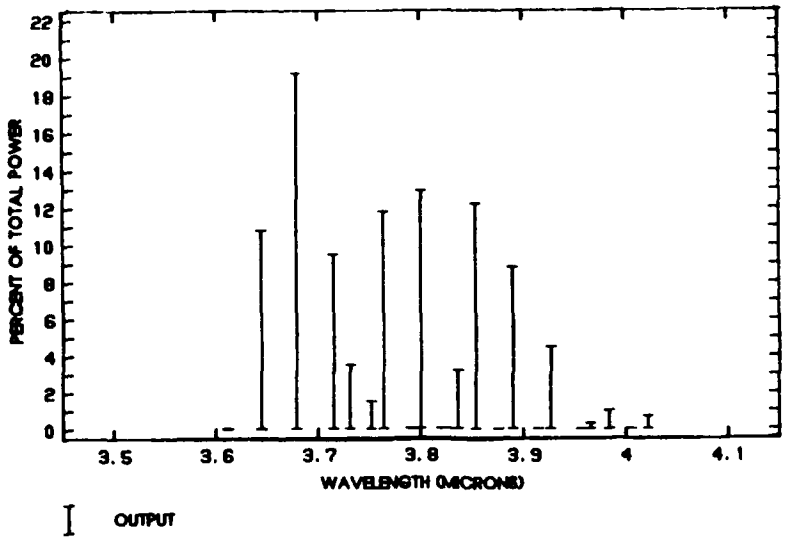

Figure 1. MIRACL output spectrum for 41 percent power.

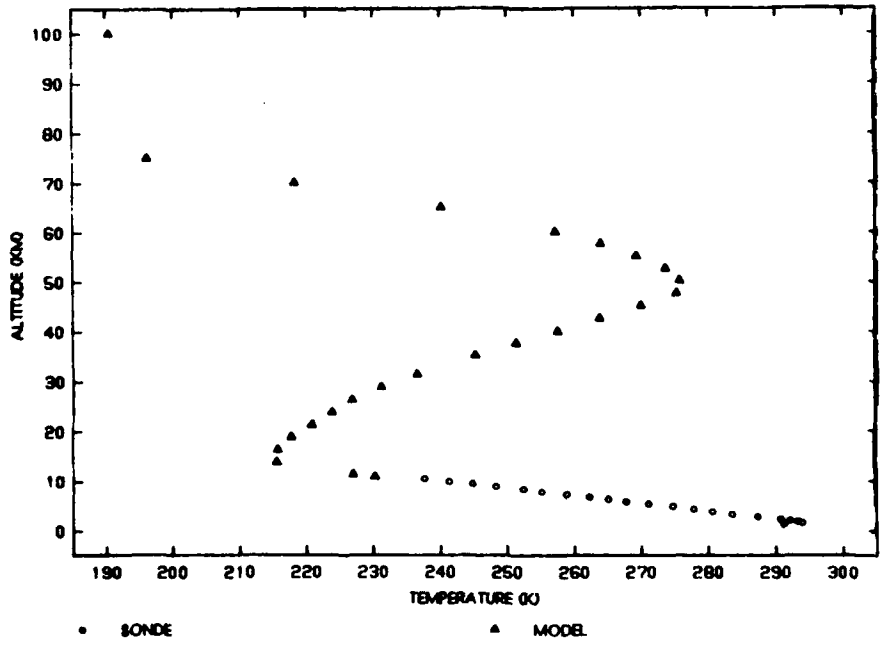

Figure 2. Atmospheric temperature profile for 1.25 to 100 km.

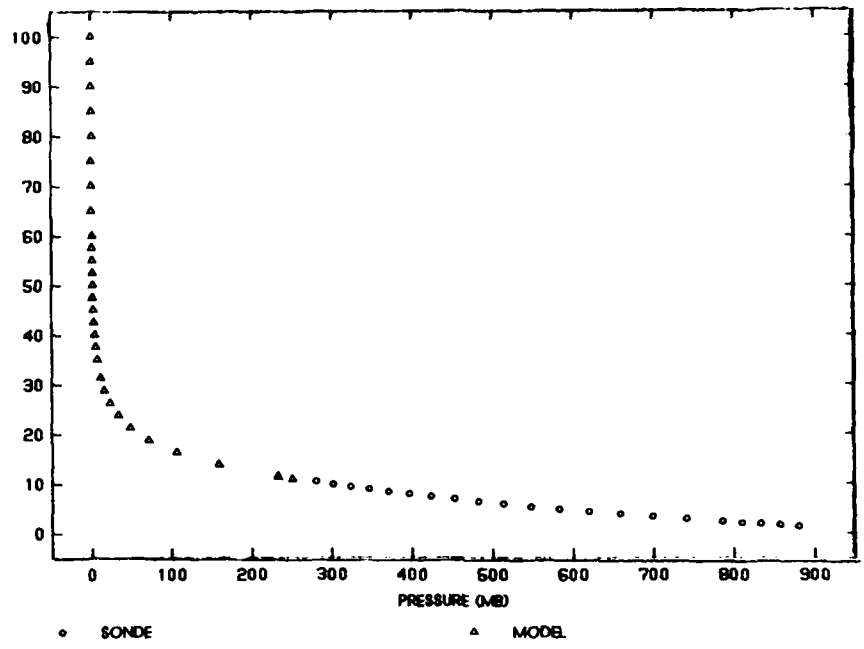

Figure 3. Atmospheric pressure profile for 1.25 to 100 km.

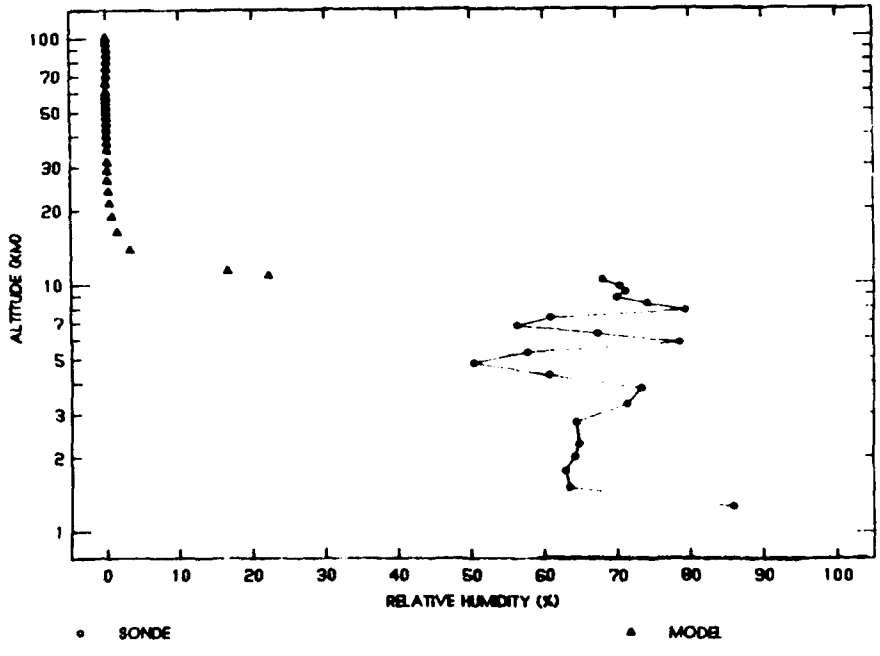

Figure 4. Atmospheric relative humidity profile for 1.25 to 100 km.

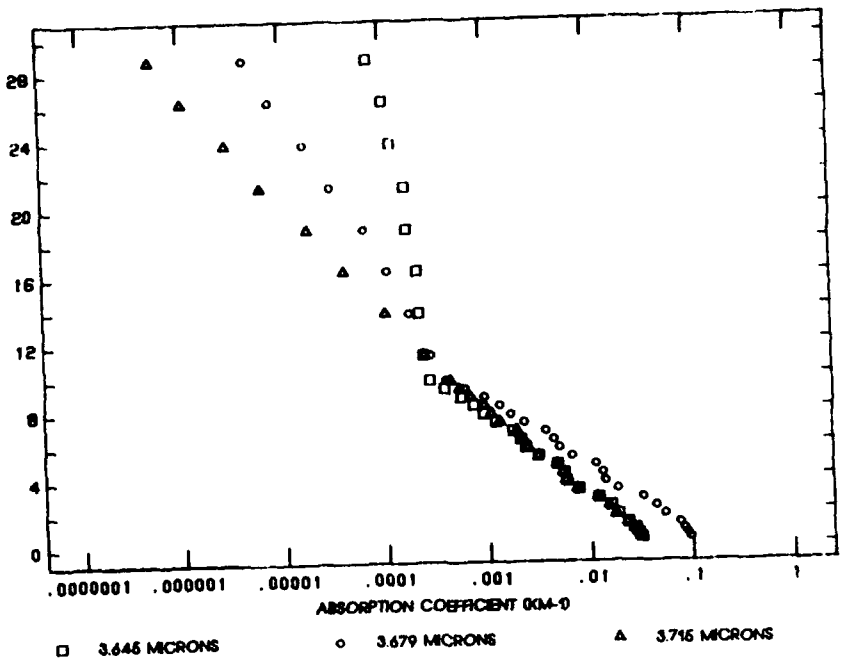

Figure 5. Molecular coefficients for 3.645, 3.679, and 3.715 μm.

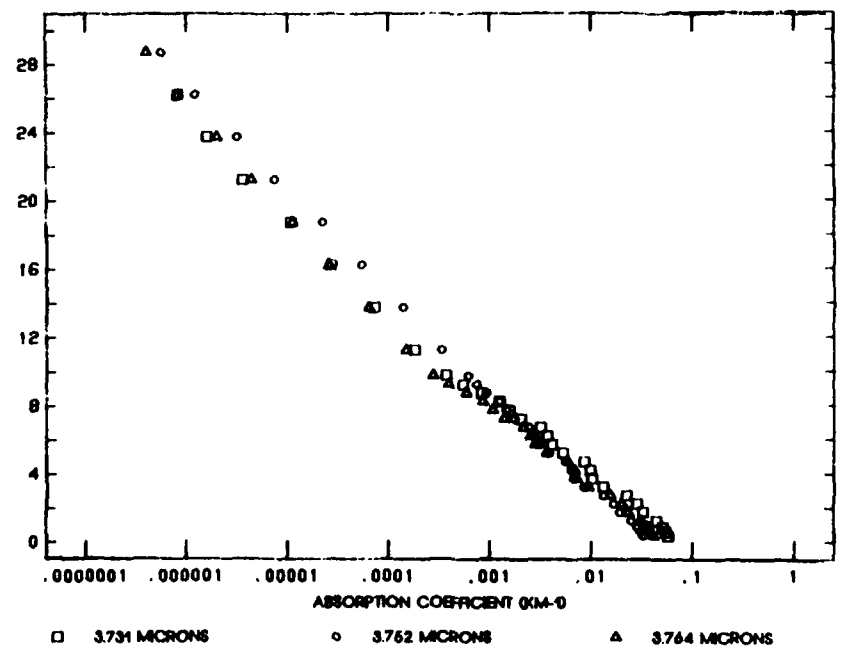

Figure 6. Molecular coefficients for 3.731, 3.752, and 3.764 μm.

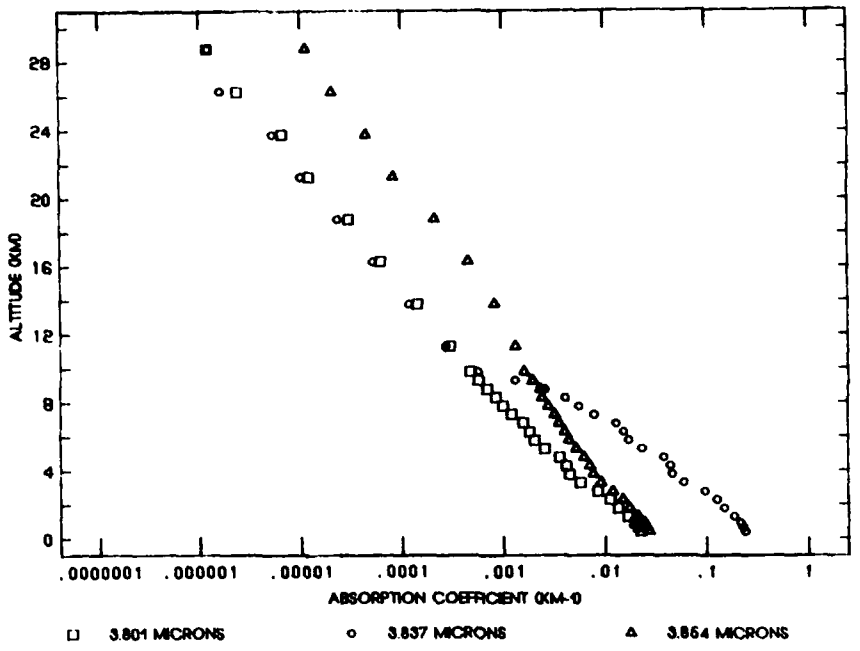

Figure 7. Molecular coefficients for 3.801, 3.837, and 3.854 μm.

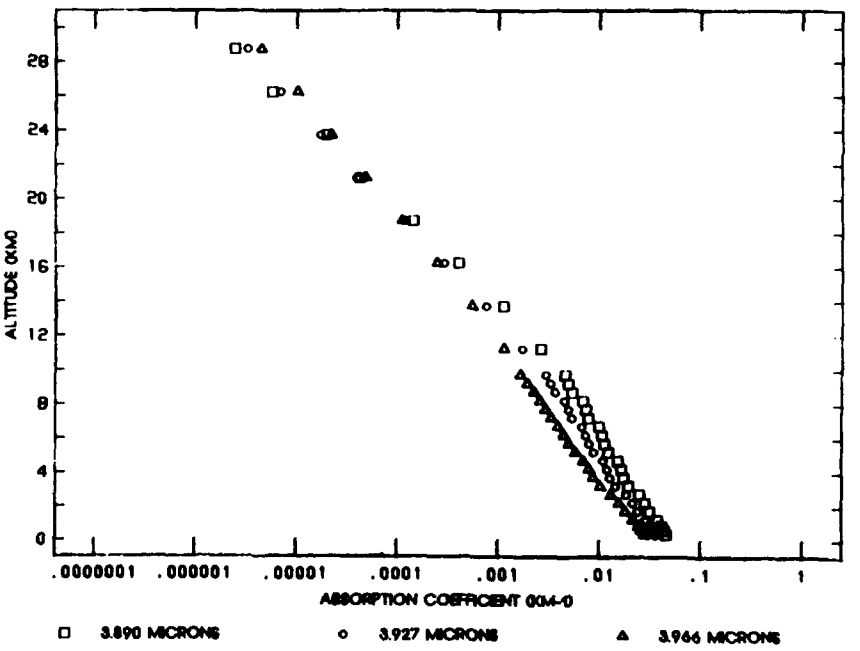

Figure 8. Molecular coefficients for 3.890, 3.927, and 3.966 μm.

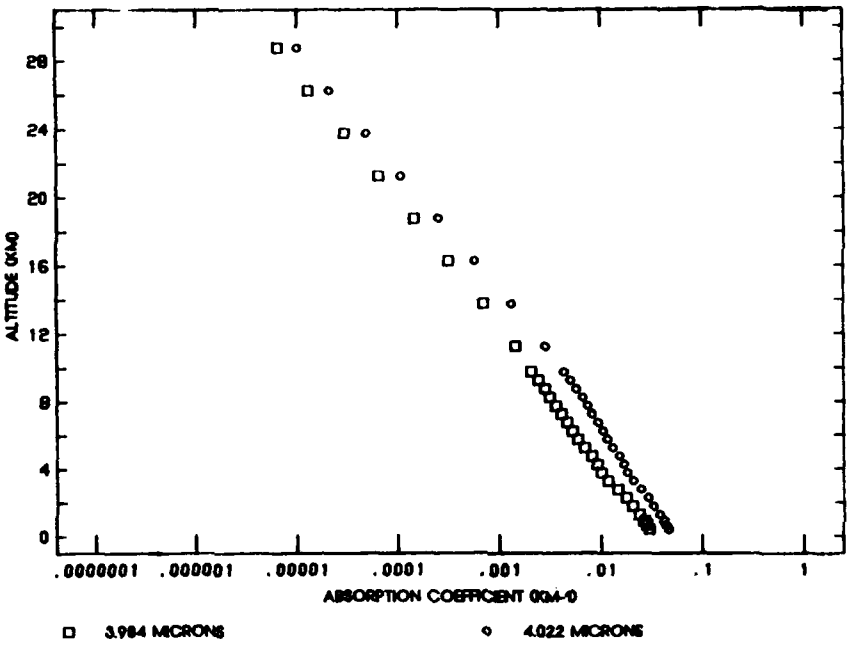

Figure 9. Molecular coefficients for 3.984 and 4.022 μm.

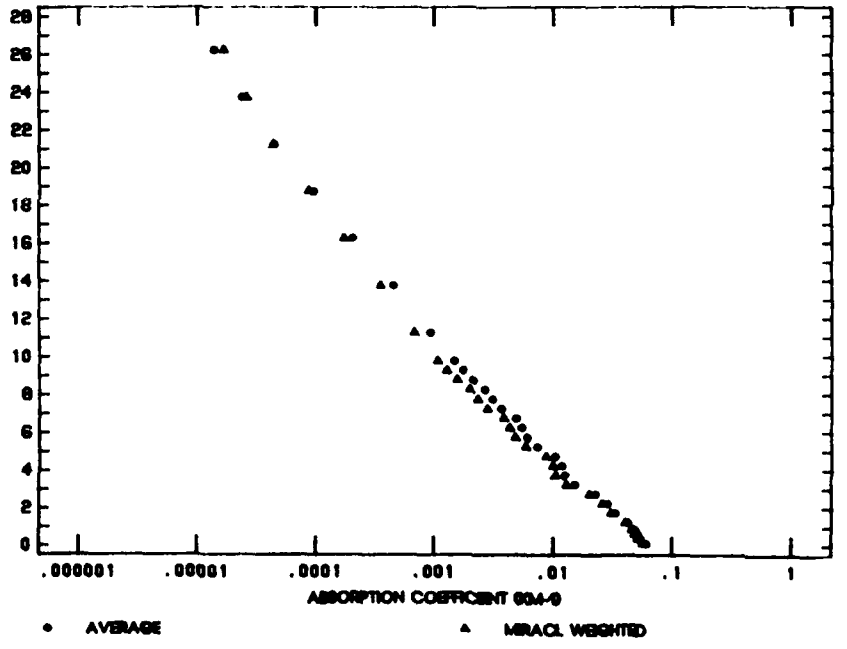

Figure 10. Averaged and weighted molecular absorption coefficient for MIRACL power of 41 percent.

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